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TECHNICAL REPORT

Review of the Literature and On-going EPA Projects Comparing Portable Dosimeters and Fixed Site Monitors as Accurate Indicators of Exposure to Carbon Monoxide

by

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NOTICE

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Introduction

The primary source of carbon monoxide (CO) present in the atmosphere is the incomplete combustion of gasoline-fueled cars with carbureted, spark-ignition reciprocating engines. The CO emitted is a function of concentration of CO in the exhaust gases, flow rate of exhaust gases and duration of operation (1). Future exposure to ambient CO concentrations will clearly depend on future amounts of CO emitted into the atmosphere and future CO emission patterns. As mandated by Section 319 of the Clean Air Act, substantial effort has been expended by the U.S. Environmental Protection Agency (EPA) to quantify the extent of CO exposure to the U.S. population. EPA and various state and local environmental quality agencies have promulgated standards for CO reduction based on measurement of CO at fixed site monitors located throughout these areas. Whether CO levels measured at these fixed site monitors are indicative of personal CO exposure has recently been examined by several investigators (2,3,4). These studies raise some important questions as to whether personal dosimeters may be a better indicator of exposure and biological dose than fixed site monitors and whether fixed site monitor concentrations correlate with biological dose.

This report will be primarily concerned with reviewing and evaluating previous studies comparing personal dosimeter readings and fixed site monitors. The secondary objective will be to assess the correlation, if any, of either or both of these monitoring techniques to various biological measurements of CO exposure including "end-expired" breath analysis and blood carboxyhemoglobin (COHb). An accurate assessment of the above parameters is essential especially in urban areas where CO levels above the National Ambient Air Quality Standard (NAAQS) of 10 mg/m^3 (9 ppm) for an eight-hour limit and 40 mg/m^3 (35 ppm) for a maximum one-hour limit have been reported.

The following studies in the literature related to personal dosimetry and fixed site monitors have been evaluated in depth:

- Cortese and Spengler (Boston) study (2)

- Jabara, et al. (Denver) study (3)

- Wallace (Washington, D.C.) study (4)

- Wilson and Schweiss (Seattle) study (5)

- Wilson and Schweiss (Boise) study (6)

Where necessary, the significance of the findings in terms of comparing the two methods of CO exposure monitoring has been reassessed by additional statistical analysis*. In addition, the on-going short-term and long-term EPA projects on CO monitoring will be described. Hopefully these EPA projects will provide a more complete data base in this area than the aforementioned studies.

*(Note: We wish to thank Mr. James Jabara of the U.S. Army who conducted the Denver study for providing us with the original data on which further calculations were made.)

Boston Study:

Cortese and Spengler (2) conducted a monitoring study of sixty-six (66) nonsmoking individuals who commuted by several means of transportation to different locations in the Boston metropolitan area. The primary purpose of the study was to determine whether 1 hour concentrations of CO during commuting exceeded the NAAQS. Eight-hour CO dosimeter readings were also taken. Results from personal dosimeter monitors were used to determine commuting exposures and integrated 1 hour and 8 hour exposures were determined. Personal dosimeter exposure data were compared to concentrations measured at fixed location monitors operated by the Massachusetts Bureau of Air Quality Control at urban locations near the employment of most of the commuters and suburban locations. Alveolar air samples were taken by each participant before and after each commuting trip to estimate the amount of CO absorbed by the blood during commuting.

The mean personal 1-hour commuting exposures measured by dosimeters was 1.4 times greater than the hourly reading of the fixed site monitors at urban locations (10.8 ± 5.1 ppm for a mean personal exposure 1-hour concentration compared to a mean hourly fixed location concentration at the urban stations of 7.8 ± 4.9 ppm). The mean maximum 1 hour personal exposure concentration was 2.1 times the mean concentration (5.1 ± 2.9 ppm) of the fixed site readings at suburban locations. Cortese and Spengler also examined the relationship at the range of concentrations closest to the NAAQS (the upper 5-7% of the personal exposure and fixed location measurements). The mean personal exposure concentration (25.3 ppm) was 1.6 times the mean concentration at all fixed stations (15.6 ppm) and 1.3 times the mean concentration at urban stations (19.9 ppm).

In contrast to the 1-hour exposure data, a comparison of maximum 8 hour mean personal exposure readings with those measured at fixed site monitors showed the mean 8 hour fixed site urban station readings (6.6 ppm) to be 1.6 times higher than the mean 8 hour personal dosimeter hourly average (4.2 ± 1.9 ppm). Average concentrations at suburban fixed site monitors were similar to the 8 hour average personal dosimeter readings. Table 1 summarizes the results of the Cortese and Spengler study.

Table 1

Summary of Cortese and Spengler Study

Measurement From	Compared To	Result
Commuter Personal Dosimeter 1-hr average	Urban Fixed-Site Monitor, 1-hr average	Personal Dosimeter higher by a factor of 1.4 (ave.) to 2.1 (max.)
Commuter Personal Dosimeter 8-hr average	Urban Fixed-Site Monitor, 8-hr average	Personal Dosimeter lower by a factor of 0.63
Commuter Personal Dosimeter 8-hr average	Suburban Fixed-Site Monitor, 8-hr average	Personal Dosimeterr about the same as fixed-site monitor

The alveolar air sample measurements showed no relationship with commuting CO exposure measured by dosimeters. Although actual data on alveolar "end-expired" breath samples are not presented by Cortese and Spengler, they imply that there was essentially no difference between before and after commuting alveolar air concentrations of CO. The basic premise upon which these results are valid concerning biological dose of CO is if "end-expired" breath samples are truly indicative of blood COHb and/or dose. Cortese and Spengler state the following on this subject concerning the relatively low CO exposures measured:

> "It is also difficult to measure blood COHb levels below 2% [references deleted] and the data relating alveolar air concentration to blood COHb at such levels are sparse and difficult to interpret. Therefore, alveolar air samples may not reflect the slight changes in COHb concentration that occur from ambient CO exposure." (2)

Denver Study:

Jabara, et al. (3) evaluated the occupational exposure to CO of Denver traffic officers during eight hour work shifts by comparing personal dosimetry, before and after workshift breath samples analyzed for CO, and ambient CO levels at fixed site monitors. The study design was a structured random sampling of volunteers separated into control and exposed groups by shift and job classification. At the beginning of each shift, dosimeters were distributed to three exposed and one control volunteer and breath samples were taken. The controls were police department employees who worked at the traffic bureau but remained indoors during working hours. The exposed group consisted of traffic officers working at urban traffic locations. At the end of the work shift, breath samples from all participants were collected, dosimeter readings were recorded and questionnaires concerning smoking habits were returned and the information recorded. Breath samples were analyzed by the method of Jones, et al. (7) and were collected in the same manner as in the Boston study. The average ambient CO levels monitored at fixed sites were also recorded on the same day as the personal monitoring took place. Ambient concentrations of CO were determined by reference to the three nearest fixed site monitors within the Denver metropolitan area to the traffic officers in the field.

Figure 1 presents the average daily dosimeter readings for the subjects and controls compared to the ambient CO concentrations. Statistical analysis by Jabara, et al. showed a significant difference between subjects and controls. Of particular interest to this paper, however, was whether the dosimeter readings of controls who may be more representative of the environmental exposures expected in the general community (the majority of their time is indoors), was significantly different than the ambient readings at fixed site monitors*. Jabara's survey data were obtained and statistical analysis was performed on the matched sets of data by the "Student" t-test, which is used to detect significant differences between independent groups or several different observations for each individual within a group. A significant difference ($0.0005 < P < 0.005$)** was found between control dosimetry values and ambient CO from fixed-site monitors, with as shown in Figure 1, the dosimeters indicating a higher value than the fixed-site monitors. As could be expected from Jabara's initial analysis of variance of the subject and control data, the "Student" t-test showed a signficiant difference ($P < 0.0005$) between matched observations of subject dosimetery values and ambient CO from fixed site monitors. Table 2 summarizes the exposure data from the Denver study.

* The author acknowledges that indoor air pollution factors such as underground garages and cigarette smoking may have been a factor in these results, but the controls were not exposed to CO as commuters, therefore reducing this aspect of their exposure; it is not known if these balance out.

** The author would like to thank Mr. Martin Atherton of the EPA Office of Mobile Source Air Pollution Control for performing the statistical analysis of the original data provided by Mr. Jabara.

Table 2

Summary of Denver Exposure Data

	Number	Mean PPM	Standard Deviation
Ambient CO fixed site monitors- 8-hour average	98	6.4	3.2
Dosimeter Readings - 8-hour average - All participants*	98	18.9	10.4
Dosimeter Readings - 8-hour average Subjects	75	21.7	9.9
Dosimeter Readings 8-hour averages- Controls	19	9.9	5.9

* 4 Dosimeter readings could not be classified as either subjects or controls because of mixed exposures but were included for this data analysis.

Jabara determined the correlation coefficients between the different parameters measured in the study for smoking and nonsmoking subjects. These data, shown in Table 3, show that smoking greatly influenced COHb levels determined by before and after shift breath analysis. The non-smoking subjects correlations did show some significant results. The relationship between dosimeter and after shift breath analysis (r = .82) showed that dosimeter readings are a good indicator of COHb at the end of the shift. This result was in contrast to the previously mentioned Boston study. The dosimeter versus change in breath (after-shift breath CO level minus the before shift breath CO level) relationship for nonsmoking subjects in the Denver study also indicated a significant correlation (r = .64). These relationships for nonsmokers are important in terms of EPA's proposed revisions of the CO standard (45 Federal Register 55066, August 18, 1980) because EPA has considered only nonsmokers in evaluating COHb data. Another important relationship to point out is that the dosimeter readings and fixed site monitor data do not correlate well for nonsmokers (r = .3990) and smokers (r = .2119).

Table 3

Correlation Coefficients Between Measured Data for Smoking and Nonsmoking Subjects for Denver Study

	Smokers	Nonsmokers
1. Dosimeter vs. After	.1829	.8228
2. Dosimeter vs. Change	.4947	.6431
3. Before vs. After	.8171	.3091
4. Before vs. Ambient	-.1483	.3631
5. Dosimeter vs. Before	-.1292	.2177
6. Dosimeter vs. Ambient	.2119	.3990
7. Before vs. Change	.0409	-.4051
8. After vs. Ambient	.0139	.3018
9. After vs. Change	.6094	.7443
10. Ambient vs. Change	.2280	.0381

NOTES: Dosimeter: Personal breathing zone sampling for CO, with an integration of the CO dose over the entire workshift (8-hour time-weighted average). Ambient: Stationary site sampling for CO, 8-hour moving average. Before (breath): Personal measurement of CO in the workers' expired breath before the workshift. After (breath): Personal measurement of CO in the workers' expired breath after the workshift. Change (in breath): After-shift breath CO level minus the before-shift breath CO level. (Adapted from Reference 2)

Further statistical analysis was performed with Jabara's data to determine whether work-related proximity to traffic congestion was related to dosimeter readings. Traffic officers who Jabara had separated by job classification were grouped in ascending order of proximity to auto traffic congestion and coefficients of correlation were determined for exposure class versus dosimeter and before and after breath analysis. Work related proximity to traffic congestion correlated fairly well ($r = .625$) with the 8 hour average dosimeter reading but did not correlate as well, if at all, with after shift breath analysis ($r = .140$) and change in breath ($r = .360$).

Washington, D.C. Study:

Wallace of EPA's Office of Monitoring and Technical Support reported CO concentrations inside vehicles of commuters travelling to and from Washington, D.C. from Reston, Va. during the summer of 1978 (4). Dosimeter readings taken inside the vehicle (most often on the rear seat) were compared to ambient CO readings obtained from a Washington, D.C. fixed site monitor. Although the intent of the Wallace study was to examine intrusion of CO into automobile and bus interiors, the results of the study point out the difference in results between dosimeters located fairly close to commuters (perhaps more indicative of personal exposure) and fixed site monitors.

Mean CO concentration for all vehicles (buses and automobiles) was 11.7 $\pm$ 4.9 ppm. The values in the interiors of the vehicles during city driving averaged 50% higher than during suburban driving. The difference was significant at the $p < .01$ level. Ambient levels measured by the fixed site monitor averaged 3.5 $\pm$ 1.6 ppm in the city. Even vehicles in the suburbs, where ambient levels are presumed to be lower, contained concentrations more than twice as great as ambient levels measured by the fixed site montior in the city. It should also be noted that although a considerable portion of commuting time was in the suburbs, mean in-vehicle concentrations were still 3-4 times the values recorded by the fixed site monitor. Figure 2 shows that ambient concentrations measured by the fixed site monitor and interior concentrations measured by the dosimeters are not related ($r = .1$). However, the five days when ambient levels were high coincided with the high exposures inside the vehicles probably indicating the communter's high exposure as well.

Seattle and Boise Studies:

Wilson and Schweiss of EPA's Surveillance and Analysis Division Region X prepared reports on the work performed in Seattle (5) and Boise (6) of the extent of CO in these urban areas. Although these studies cannot be used to compare fixed site monitors and personal dosimeters, they did examine the correlation between ambient CO at fixed site monitors and CO concentrations at street level bag samplers and indoor locations which were believed to more accurately reflect actual human exposure.

The Seattle study involved a 20-day monitoring for CO at 36 outdoor sites, five indoor sites, and two pedestrian walking routes in downtown Seattle. For the 36 outdoor sites, bag samplers were placed at representative locations some of which were expected to yield low CO values because of remoteness from cars. Locations where idling vehicles occur were deliberately avoided. At each site, the sample inlet was about 3.5 meters above the sidewalk, more than 10 meters from an intersection and more than 2 meters from a vertical walk. Most samples were over one meter from the street curb; two were at a much greater distance (in parks). These bag sample results were compared to the five permanent monitoring sites located in the downtown area. The Boise study design was similar and involved 40 outdoor sites, six indoor sites, and two pedestrian walking routes. In Boise, there is only one continuous monitor to compare CO data. Indoor sites in the Boise study, as in the Seattle study, were chosen within a few blocks of the permanent monitor(s) and data from these sites were compared to the adjacent outdoor sites. Indoors sites were equipped with bag samplers and continuous analyzers to monitor the daily pattern of indoor CO levels.

The Seattle data show that the permanent monitoring network was not representative of the highest frequency of exceedences of the 9 ppm NAAQS within the study area for the twenty day period. The eight-hour standard was exceeded at one or more sites on 80% of the study days. Exceedences at one or more of the permanent monitors occurred on 45% of the sampled days. Each day the highest eight-hour average for any of the five permanent monitors was compared to the highest eight-hour average at any of the study sites. On most days, the maximum CO average at the study site was less than 1.5 times that at the maximum permanent monitor, but on six days was over 1.5 times as great. On four of the days when no violations were observed at the permanent monitors, the maximum study site's eight-hour average exceeded 9.0 ppm and was more than 1.5 times greater than at the permanent monitor.

The Seattle data was also analyzed to look at the 20 day average CO concentrations measured by stationary monitors and those by the two nearest experimental samplers. Table 4 presents these data and shows that seven of the ten averaged values are only marginally higher than their matched counterparts. Linear regression analysis of these averaged values revealed fairly good correlation (r^2 = .6) between the experimental and fixed site measures.

Table 4

Twenty Day Average CO Concentrations
Stationary Monitors vs. Experimental Samplers
Seattle, Washington

Station Site	CO Concentration PPM					
	Stationary Monitor		EPA Site #1		EPA Site #2	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Pike Street Station	8.0	4.5	5.5	3.4	8.2	3.0
University St. Station	6.0	3.5	6.4	4.0	6.6	3.0
James Street Station	4.4	4.2	3.9	3.0	5.5	2.6
Fire Station	2.3	2.3	5.1	2.8	2.9	1.1
Smejcor Street Station	5.5	3.6	5.4	3.0	6.0	1.7

Paired average concentration values for Seattle indoor/outdoor measures appear in Table 5. Three of the five grouped averages are higher for indoor measures than those outdoors. Wilson and Schweiss concluded that changes in CO concentrations at outdoor sites frequently coincided with changes in CO concentrations at indoor sites, but the relationship between indoor and outdoor values was not constant.

Table 5

Average Concentration CO Values for Indoor/Outdoor Sites
Seattle, Washington

Sample Site Pairs	CO Concentration Means (PPM)
Indoor	7.6
Outdoor	6.6
Indoor	5.4
Outdoor	5.5
Indoor	6.0
Outdoor	4.5
Indoor	5.2
Outdoor	6.3
Indoor	8.2
Outdoor	5.5

The Boise study data indicate that the fixed site permanent monitors gave CO readings generally lower than the experimental stations. On every day but one of the twenty day study, the eight-hour concentration at the permanent monitor was exceeded at one or more study site. Wilson and Schweiss conclude, "the permanent monitor was generally representative of the higher concentrations but did not represent the highest concentrations or frequency of exceedences within the study area." On 95% of the study days (19 of 20) the eight-hour NAAQS was exceeded at one or more experimental sites. Exceedences at the permanent monitor occurred on 47% (9 of 19) of the sampled days. The Boise study found that changes in CO concentrations at outdoor sites frequently coincided with changes in CO concentrations at indoor sites, but the relationship between indoor and outdoor values was not constant. Concentrations were usually lower indoors than at the adjacent outdoor site in this limited study.

Other Considerations in the Literature:

In addition to the studies described above, several other studies have reported on the relationship between fixed site monitors and personal dosimeters. Studies by Ott and Eliassen (8), Godin et al. (9) and Wright et al. (10) have shown that pedestrians on downtown urban streets are exposed to CO concentrations that exceed the NAAQS that are not being observed at fixed site monitoring stations. CO dosimeter concentrations were substantially higher than concentrations measured by fixed site monitors. Other work has been performed on CO "hot spots" (11), areas such as major urban intersections where CO levels may be highest. Further analysis of this study performed in San Jose, Chicago, Seattle and Phoenix is required to determine the relationship between CO hot spots and fixed site monitor readings.

Another consideration is the sampling height of air quality monitors and their effect on CO concentration. Johnson et al (12) discovered that elevating the sampling height from the breathing zone (5.5 ft) to the height of most fixed site monitors will produce decreases in CO concentration of between 5 and 15%. A further study in this area by Brice and Roessler (13) on horizontial and vertical CO concentrations found that mobile individuals are exposed to CO concentrations different than those measured at fixed sites. In the study of six cities of the Continuous Air Monitoring Program (CAMP) of EPA, integrated 1/2 hour CO samples taken within automobiles in traffic were compared to fixed site monitor readings. The ratio of simultaneous concentrations of CO in traffic to concentrations at fixed site monitors ranged from 1.3 to 6.8.

<u>On-Going EPA Projects</u>:

To establish a more complete data base on fixed site monitor readings, personal dosimeters and general population CO exposure and applicability of these measurements to biological dose, EPA has established a multi-faceted research program to answer the questions raised in the previously mentioned studies. Short-term studies have recently been completed or are near completion to examine individual variation of CO exposures and microenvironment exposures to CO. A microenvironment is defined as a discrete place (e.g. underground parking garage, shopping center) or location (urban street) which may have a specific CO level different from other microenvironments. A person's total exposure to CO would be the result of the CO exposures received in each microenvironment. Longer term studies will be larger in scope and will try to relate individual activity patterns to CO exposure in determining a complete profile of CO exposure to the general population.

The initial short-term monitoring study was conducted in Los Angeles by an EPA contractor, Science Applications, Inc. (SAI). Nine volunteers carried dosimeters in their daily activities to determine the reliability of state-of-the-art personal exposure monitors. In the first phase of the project conducted September-December 1980, 9 volunteers carried CO detectors to various locations during the course of ordinary workday and weekend activities for 45 days each, recording their activity and integrated CO exposures. Preliminary analysis indicated that automated data loggers were required for the general public to use these monitors in a large scale study. A total of 10 were designed and constructed by SAI and appear to satisfy this need. Further work indicated that the CO detectors were usable and the integrators provided the ability to collect data in environments with rapidly varying CO levels. The data collected will be compared to ambient CO levels measured at fixed site monitors. A draft report on SAI's work is expected in June, 1981.

In addition to the CO monitoring work in Los Angeles, other contractors have recently completed the experimental parts of monitoring studies from January-March 1981 in Denver, Co., Phoenix, Az., and Stamford, Ct. These cities were selected because of previous histories of high CO levels above the NAAQS. One of the main objectives of these monitoring studies is to accurately assess CO exposures to individuals in the population during their daily activities. Contractor personnel took dosimeter readings in simulated human activities by driving in commuter traffic and entering offices, shops and public areas, and in residential areas. The dosimeter readings taken in the downtown areas will be in close proximity to the CO fixed site monitor and will be compared to determine if the fixed site monitors are representative of CO concentrations along commuting routes and other monitored locations. These data will serve to expand the information data base of exposure to CO temporally and in various activities and locations. GCA Inc. is obtaining these measurements in Stamford while PEDCo Environmental, Inc. and Systems Sciences Software, Inc. are performing these tasks in Denver and Phoenix, respectively. The contractors will obtain the measurements and do limited analysis. EPA will perform additional data analysis and prepare a comprehensive report that will be released later this year.

Other data related to CO exposures in microenvironments have been collected by Dr. Wayne Ott of Stamford University and EPA's Office of Research and Development. He has conducted field studies of CO exposures of occupants of motor vehicles on El Camino Real in California, a one year study that will give data on urban arterial highway CO exposure. Dr. Ott also has collected field data on CO levels in commercial settings.

The objective of EPA's long term CO studies is to develop a methodology that can identify a distribution of the number of people exposed to various levels of CO averaged over appropriate times, e.g., one hour or eight hours. Two approaches are being taken to address this problem. The first approach, being coordinated by Dr. Wayne Ott is the development of a model that will predict, based on field and activity pattern data, the CO exposure of individuals in the urban population. CO exposure data of microenvironments collected from the four contractor studies and subsequent work by Dr. Ott and ORD staff will be applied to the Simulation of Human Air Pollution Exposures (SHAPE) computer model. The program combines activity profiles with data on CO concentrations in specific microenvironments and urban background concentrations in order to calculate integrated exposures of a large number of persons over a 24-hour period. The second approach is a comprehensive monitoring program of an urban population with approximately 100 volunteers or more participating.* The approach of this study would be to identify representative people, equip them with personal CO exposure monitors, have them record their CO exposure and then take the results of these exposures and extrapolate the exposures to the urban population. This study is planned to be performed over several years in different urban areas to estimate the frequency distribution of CO exposures during a full year for the subject population. These data will be compared to fixed site ambient CO readings to determine the relationship of these two parameters for different activities.

* As of May, 1981, EPA has not formalized the details of this work.

Several parts of the long-term program are presently underway. The EPA Office of Research and Development (ORD) is developing screening techniques to select typical volunteers to carry CO monitors. ORD is also evaluating whether it is better to have many individuals carry the monitors for short periods of time or fewer individuals carry them for shorter periods of time. This evaluation will depend on whether daily CO variation is greater or less than person-to-person CO variation. ORD is also developing a questionnaire to administer to people carrying the CO monitor so that they may accurately and easily record their daily activities. Evaluation of CO monitoring instrumentation is also presently being performed by EPA's Environmental Monitoring and Support Division. The contract for actual monitoring of volunteers is expected to be awarded in 1982 or 1983.

CONCLUSIONS

Accurate determinations of community exposure to carbon monoxide are needed to determine whether the NAAQS is being met and whether CO levels as measured by fixed site monitors reflect its demonstrated health risk. Review of the data on the relationship of fixed site monitor concentrations and personal dosimeter readings and the accuracy of these readings to human exposure has led to the following conclusions.

1) Fixed site air quality monitors underestimate short term variations in CO exposure. Fixed site monitors are not good measurements of exceedences of EPA's one-hour NAAQS for CO. This conclusion is in general agreement with Goldstein and Landovitz's study of fixed site air quality monitors in New York City (14). Cortese and Spengler (2) found that mean personal 1-hour commuting exposures measured by dosimeters were 1.4 times greater than the hourly readings of fixed site monitors in urban locations of Boston, Massachusetts.

2) For commuting and urban pedestrian exposures urban fixed site monitors underestimate CO exposure. Studies by Wallace (4) and several authors (8,9,10) support this conclusion. Further work is being performed by EPA to quantify this relationship.

3) Data on eight-hour CO exposures tend to show that fixed-site monitors underestimate personal exposures by dosimeters but some evidence is contradictory. Data from EPA studies now underway at Stamford Ct., Los Angeles, Ca., Phoenix, Az., and Denver, Co., should provide a more definitive statement on this topic.

   It is realized that the 8-hr CO NAAQS is the critical issue with respect to the level of control needed from mobile sources. The 1-hr CO level is assumed by the EPA Office of Air Quality Planning and Standards (OAQPS) to be related to the 8-hr average CO value. Our previous conclusions show how 1-hour CO exposures are underestimated by the fixed site monitors. However, no advice can be given as to the ratio of fixed site monitor 8-hour average readings to dosimeter 8-hour averages. The studies in this report put some doubt on whether this ratio is unity.

4) The fixed-site monitoring system does not accurately assess the extent of CO problems in U.S. cities. CO levels at urban locations often exceed the NAAQS and are not observed at the fixed site monitors.

5) The relationship of fixed site monitors and/or personal dosimeter readings to biological dose is unclear. Smoking has been shown to interfere with any relationship that may exist between personal dosimetry readings and biological dose. The studies on alveolar "end-expired" breath samples and dosimetry readings are contradictory. It is recommended that any further EPA work in this area include a complete analysis of fixed site and personal dosimetry readings, along with blood COHb and "end-expired" breath samples to find the relationship between these parameters.

References

1. U.S. Environmental Protection Agency, Air Quality Criteria for Carbon Monoxide, EPA-600/8-79-022, Environmental Criteria and Assessment Office, Office of Research and Development, Washington, D.C., October, 1979.

2. A.D. Cortese, and J.D. Spengler, "Ability of Fixed Monitoring Stations to Represent Personal Carbon Monoxide Exposure", J. Air Poll. Control Assoc., 26, 12, 1144-1150, 1976.

3. J.W. Jabara, T.J. Keefe, H.J. Beaulieu and R.M. Buchan, "Carbon Monoxide Dosimetry in Occupational Exposures in Denver, Colorado", Arch. Env. Health, 35, 198-204, 1980.

4. L.A. Wallace, "Use of Personal Monitor to Measure Commuter Exposure to Carbon Monoxide in Vehicle Passenger Compartments", Paper No. 79-59.2. Presented at the 72nd Annual Meeting of the Air Pollution Control Association, Cincinnati, Ohio, June, 1979.

5. U.S. Environmental Protection Agency, Carbon Monoxide Study, Seattle, Washington, October 6 - November 2, 1977, Prepared by C.B. Wilson and J.W. Schweiss, EPA 910/9-78-054. U.S. Environmental Protection Agency, Region X, Seattle, Washington, December, 1978.

6. U.S. Environmental Protection Agency, Carbon Monoxide Study, Boise, Idaho, November 25 - December 22, 1977. Prepared by C.B. Wilson and J.W. Schweiss, EPA 910/9-78-055, U.S. Environmental Protection Agency, Region X, Seattle, Washington, December, 1978.

7. R.H. Jones, M.R. Elliott, J.B. Cadigan and E.A. Gaensler, "The Relationship Between Alveolar and Blood Carbon Monoxide Concentrations During Breath Holding: Simple Estimation of COHb Saturation", J. Lab. Clin. Med., 51, 553-564, 1958.

8. W. Ott and R. Eliasson, "A Survey Technique for Determining the Representativeness of Urban Air Monitoring Stations with Respect to Carbon Monoxide", J. Air. Poll. Control Assoc., 23, 8, 685-690, 1973.

9. G. Godin, G.R. Wright and R.J. Shephard, "Urban Exposure to Carbon Monoxide", Arch. Environ. Health, 25, 305, 1972.

10. G.R. Wright, S. Jewczyk, J. Onrot, P. Tomlison and R. Shepherd, "Carbon Monoxide in the Urban Atmosphere: Hazards to the Pedestrian and Street Workers", Arch. Environ. Health, 30, 123, 1975.

11. Analysis of Pollutant and Meteorological Data Collected in the Vicinity of Carbon Monoxide "Hot Spots", SRI International Discussion Draft Report for EPA Contract No. 68-03-2545, May, 1979.

12. W.B. Johnson, W.F. Dabberdt, F.L. Ludwig and R.J. Allen, "Field Study for Initial Evaluation of an Urban Diffusion Model for Carbon Monoxide", Report for Contract CAPA 3-68 (1-69) prepared by Stanford Research Institute for the Coordinating Research Council and the U.S. Environmental Protection Agency, 1971.

13. R.M. Bruce and J.F. Roessler, "The Exposure to Carbon Monoxide of Occupants of Vehicles Moving in Heavy Traffic", J. Air Poll. Control Assoc., 16, 597, 1966.

14. I.F.Goldstein and L. Lanovitz, "Analysis of Air Pollution Patterns in New York City - I. Can One Station Represent the Large Metropolitan Area?", Atmos. Envir., 11, 47-52, 1977.

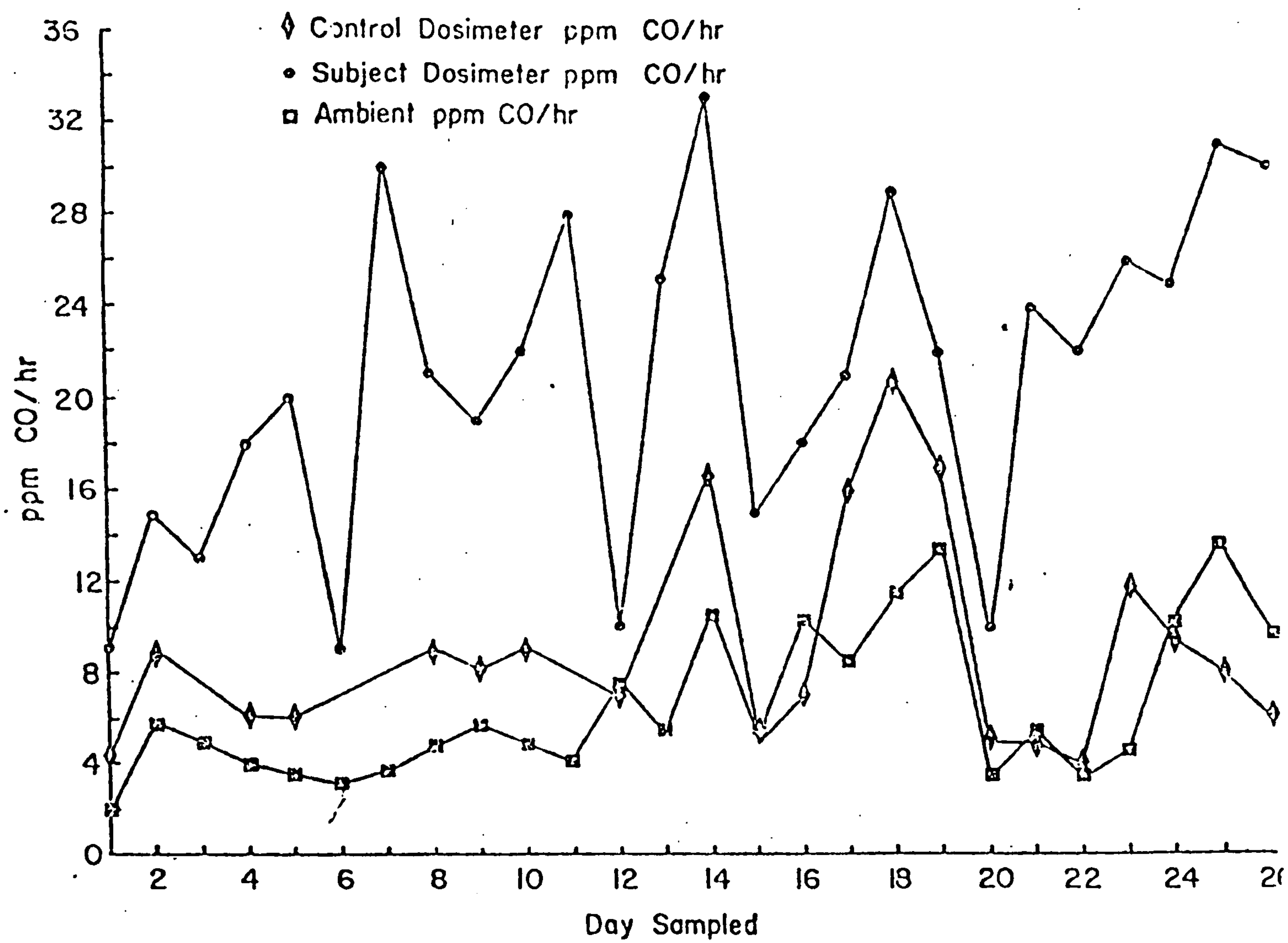

Figure 1. Average Daily Dosimeter Readings for Subjects and Controls Compared To Ambient CO Concentrations for Denver Study (From Reference 3)

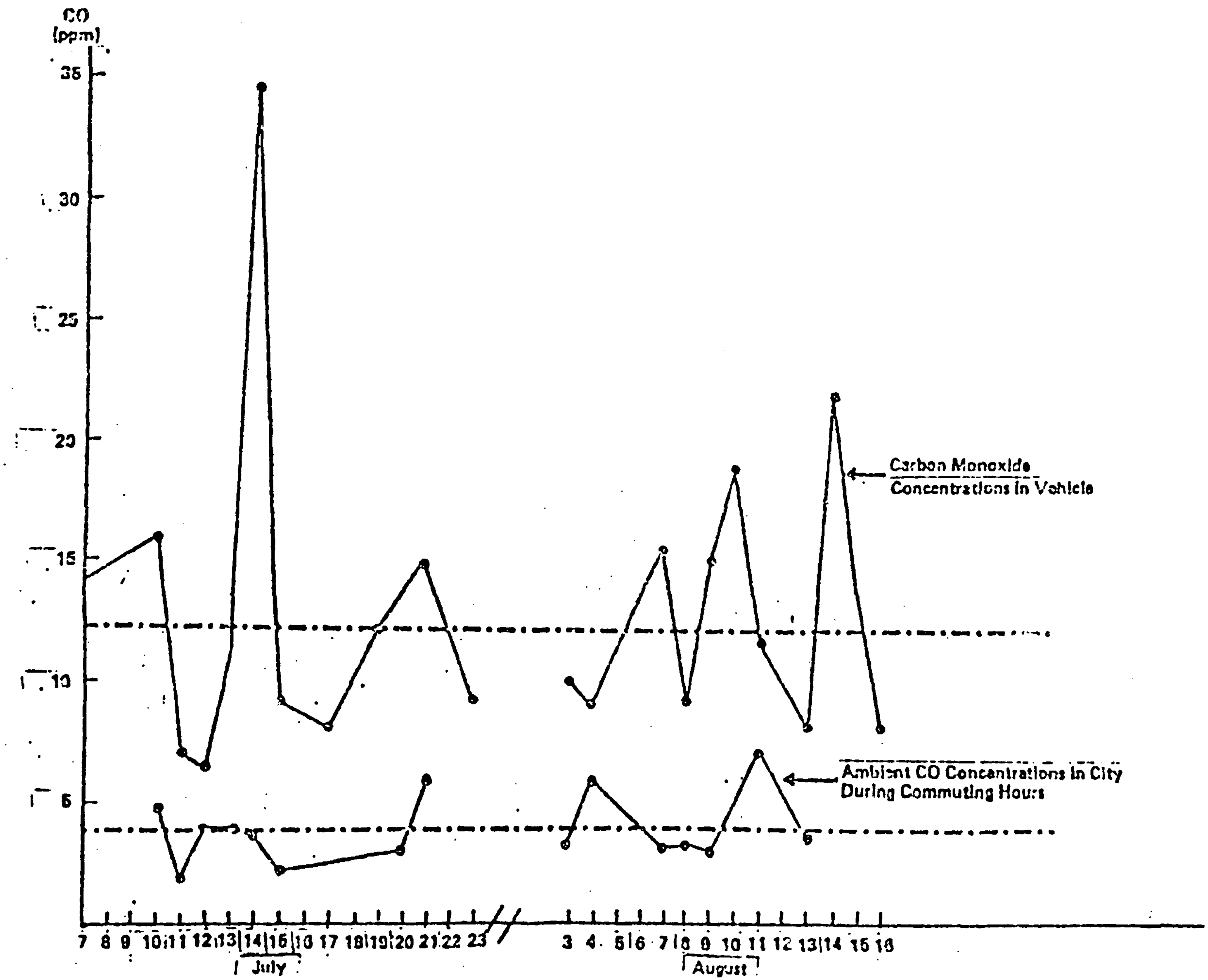

Figure 2. CO Concentrations in Vehicle Compared to Ambient CO Levels in Washington, D.C. (From Reference 4)